V. THE HISTORICAL PRICE METHOD IS THE DUAL OF THE TFP METHOD

While the economic theory of duality shows that productivity can be calculated from either the differential rates of growth of input and output quantities or prices, there are practical differences in the calculations which favor using quantity indices to measure changes in TFP. The *FFN* explores this relationship (at ¶s 84-86) between the historical price method and the TFP method for determining a productivity offset in the annual price adjustment formula for a price-cap-regulated firm. In economic theory, TFP growth and the change in unit costs can be measured using the same set of basic assumptions and the relationship between input and output quantities or input and output prices. In his classic exposition of the theory of total factor productivity measurement, D.W. Jorgenson begins with the identity that the value of output is equal to the value of input (equation (1)). He then differentiates this identity with respect to time to derive the change in TFP as the difference between Divisia quantity indexes of outputs and inputs. In a footnote, he observes that

> Any index of total factor productivity may be computed either from quantity indexes of total output and total input or from the corresponding price indexes. The whole analysis that follows could be carried out in an entirely equivalent way, using price indexes instead of quantity indexes.[40]

In particular, measurement of the change in TFP by either the price or quantity method requires the assumption that the value of input equal the value of output in each period—or at least that the data be adjusted so that this identity holds approximately in the historical period.[41]

These basic facts from the economic theory of duality have several practical consequences. First, the apparent ability of the historical price method to produce a productivity offset or a measure of productivity growth *for an individual service*—or for

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[40] D.W. Jorgenson, "The Embodiment Hypothesis," *The Journal of Political Economy*, Vol. LXXIV, February 1966 at 2-3.

[41] This dependence on the constant equality of revenue and cost over time makes intuitive sense. If a firm were to increase economic earnings rather than lower prices to reflect productivity growth, the price method applied to that data would underestimate true productivity growth. Recall that the Frentrup-Uretsky study adjusted prices to hold earnings constant. The Christensen study accomplishes this by using an independent measure of the cost of capital.

interstate carrier access services as a group—is illusory. When output price data are adjusted to keep earnings constant across the historical period, accounting costs must be assigned to individual services.[42] That assignment is no different—in principle—from the measurement of interstate access TFP growth from Part 36 and Part 69 cost and revenue data, which is acknowledged to be inappropriate. Second, while duality implies that TFP growth measured by quantities and prices will be the same, it does not suggest that failure of any of the assumptions of the method will have the same effect on the two TFP growth measures.

For example, suppose economic earnings vary from year to year during the historical period. TFP growth measured by quantities could differ markedly from TFP growth measured by prices. If prices are adjusted in each period to keep measured economic earnings constant, errors in the adjustment would affect TFP as measured by prices more than TFP as measured by quantities. Using the historical price method, TFP growth is calculated from *changes* in prices (i.e., the difference between the rates of growth of input and output prices). Using the quantity method, prices enter the TFP growth calculation only

(i) as part of the revenue and expenditure weights used to calculate aggregate quantity indices of outputs and inputs; and

(ii) as *levels* rather than annual changes.

Thus errors in measuring input or output prices (or adjusting output prices to keep accounting earnings constant) have a larger effect on TFP growth as measured by price rather than quantity. Possibly for these reasons, it is instructive to note that, without exception, empirical studies of productivity growth use quantity indices rather than price indices.[43]

Third, the practical decision whether to base historical measurements on quantities or prices must take into account the use to which the measurement will be put. In the present

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[42] Thus when NERA and Frentrup-Uretsky calculated X using the historical price method in CC Docket No. 87-313, they adjusted prices to hold earnings constant, and that adjustment required the calculation of the total cost of interstate switched access services. The calculation therefore erroneously assigns a portion of the fixed costs of the LECs to interstate switched access services and presented arbitrary and incorrect estimates of TFP.

[43] See, for example, D. Jorgenson, F. Gollop and B. Fraumeni, *Productivity and U.S. Economic Growth*, Cambridge: Harvard University Press, 1987, at 4 and 152-159.

exercise, the results will be used essentially to forecast future values of productivity growth to determine a reasonable target productivity growth for the price-cap regulated LECs. Since productivity growth—relative to U.S. average productivity growth—is the ultimate source of real price reductions in any market, it is preferable to study productivity growth directly, rather than indirectly through the price changes that follow from productivity growth. In particular, possible differences between the historical period and the future will be easier to quantify directly in terms of productivity growth than indirectly in terms of output price growth.[44]

Finally, the duality of price and output-based measures of productivity growth can be used as to check results. As discussed above, we cannot use duality to reconcile the historical price calculations for interstate switched access services with the quantity-based productivity measures calculated by Christensen: the latter applies to all the firm's services and would be comparable only to a price-based productivity study performed on all of the firm's services.

It is straightforward to compare a price-based measure of the achieved X for the telecommunications industry with the historical X calculated by Christensen. Indeed, the Commission Staff has already performed such a comparison: the Spavins-Lande studies filed in CC Docket No. 87-313 are long run measures of the X achieved by the telecommunications industry.[45] As updated through 1993 in the NERA Reply Comments, the long run (1929-1993) productivity offset calculated from telecommunications industry price data averaged about 2.1 percent, unchanged from the Spavins-Lande finding for the 1929-1987 period. Applying the method to the post-divestiture period, we find that the Spavins-Lande historical price-based value of X for the period examined in the Christensen direct studies (1984-1993) is 2.4 percent which corresponds reasonably closely with the value of X proposed by Dr. Christensen which uses the long run input price differential of 0. This

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[44] This difference is particularly relevant when prices were regulated differently between the historical period and the future. Much of the work in the original studies in CC Docket 87-313 using the historical price method was done to correct measured prices for changes over time in regulatory rules and procedures.

[45] *Supplemental Notice of Proposed Rulemaking*, CC Docket 87-313, March 12, 1990, Appendix D and *Second Report and Order*, CC Docket 87-313, October 4, 1990, Appendix D.

correspondence provides some confirmation that—at the level of aggregation of the entire firm—the historical price method and the direct TFP method yield similar results, as they should under the principles of duality.[46]

In summary, although economic theory suggests that prices and quantities can be used symmetrically to calculate productivity growth, there are serious practical concerns with historical price-based methods in these circumstances. Price-based methods can replicate accurately the outcome of historical regulation on prices and can determine an ***X*** that will assure customers that real price growth will be slower under price regulation than it had been under the historical regulatory regime. However, to give economic support to the historical price method requires (i) that prices be adjusted to undo the multitude of regulatory changes over time and (ii) that the analysis be undertaken at the level of the total firm rather than interstate services or individual services.[47] When that analysis is undertaken, we see that the historical price method yields approximately the same historical value of the X-Factor as obtained from the direct measurement of TFP growth based on input and output quantities.

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[46] Note that if the short run point estimate of the input price differential were added to Dr. Christensen's TFP differential, the correspondence between the direct and dual estimates of industry productivity would disappear. This fact implies that only the long-run adjustment for differences in input price growth rates—essentially zero—is consistent with both the empirical evidence and the implications of duality.

[47] Note that measures of the historical productivity offset based on carrier access prices proposed in this Docket do not give such support because they are undertaken for only a subset of the LEC's services.

VI. THE CONSUMER PRODUCTIVITY DIVIDEND

Paragraphs 94-95 of the *FFN* note that a consumer productivity dividend (CPD) was originally added to the historical X factor (calculated prior to price regulation) to ensure that customers benefited from the anticipated increase in the rate of growth of TFP stemming from the adoption of price cap regulation. The *FFN* then asks if a CPD should again be added to an historical X factor measured over a period in which price cap regulation were in force. There are at least two reasons why—irrespective of the announced level of the productivity offset—a continued or additional CPD is not warranted. First, adding a CPD to an historical X factor measured over a period that includes price cap regulation would effectively double-count expected productivity gains from regulatory reform. Second, interstate price caps are currently approximately 2.5 percent lower than would otherwise have been because of the 0.5 percent CPD put in place at the beginning of price cap regulation for LECs. It is unclear why a shift to an improved form of regulation in the past would continue to yield additional efficiencies in the future. One might think that a one-time reduction in prices should be required to match a one-time reduction in costs from improved regulation. However, because it is built in as part of the productivity offset, the interstate CPD automatically increases over time. Indeed, since 1991, some five years of a CPD are embedded in the LECs' current rates.

VII. CONCLUSION

Three important areas of Commission concern are addressed in this study. First, evidence regarding the magnitude and uncertainty of the measured input price differential in a price cap plan suggests that point estimates calculated over a relatively short period of time are too unreliable to support their use in a mechanical formula. If a productivity target were increased to account for the post-divestiture difference in LEC and U.S. input price growth, the LECs would be doubly penalized when interest rates begin to rise and LEC input prices begin to rise more rapidly than those of the U.S. as a whole.

Second, use of historical TFP measures to determine the productivity offset in the price adjustment formula is reasonable. Productivity growth must be calculated at the level of

the entire firm. Efforts to calculate service-specific productivity growth are misguided because the production function for telecommunications services is not separable for interstate and intrastate services, for regulated and nonregulated services, or for finer disaggregates of services. It is not possible to estimate service-specific TFP growth. Similarly, adjustments to total firm measures of productivity growth to account for differential output growth or contribution by service are also improper because there is no underlying difference in productivity growth rates across services for these adjustments to approximate.

Third, while calculating productivity growth from price or earnings data is possible in theory, it is more academic than practical. The Historical Revenue method requires that accounting measures of earnings and depreciation correspond to economic concepts and that price cap regulation have been applied correctly and consistently over the historical period. Similarly, the Historical Price Method requires that the price data be adjusted to keep measured economic earnings constant, and errors in those adjustments are likely to have a larger effect on measured TFP growth than when direct, quantity-based measures of productivity growth are calculated. But the main drawback to both approaches is that—despite appearances—they cannot produce meaningful productivity growth measures for LEC interstate services. Productivity growth for LEC interstate services calculated by these methods entails tacit assignments of fixed common costs to particular services, so that the resulting measure of productivity growth is as arbitrary as the undefined concept—the productivity growth of a subset of services connected through fixed common costs—it attempts to quantify. Such measures have no theoretical support in economics and can play no useful role in the measurement of productivity growth to set the parameters of a price cap plan.

Economic Evaluation of Selected Issues From the Fourth Further Notice of Proposed Rulemaking in the LEC Price Cap Performance Review

Attachment A

REGRESSION: TELEPHONE INPUT PRICE GROWTH - CHRISTENSEN 1 DATA

Year	LEC Input Price Change	U.S. Input Price Change	Divestiture Binary Dummy	Moody's Pub Util Bonds	1990-2 Dummy
A	B	C	E	D	E
1949	3.2%	-1.0%	0	2.66%	0
1950	5.1%	6.3%	0	2.62%	0
1951	8.8%	7.9%	0	2.86%	0
1952	8.6%	1.2%	0	2.96%	0
1953	2.4%	3.7%	0	3.20%	0
1954	1.9%	0.6%	0	2.90%	0
1955	5.4%	6.6%	0	3.06%	0
1956	1.7%	0.7%	0	3.36%	0
1957	-1.1%	3.7%	0	3.89%	0
1958	3.3%	0.5%	0	3.79%	0
1959	5.4%	7.0%	0	4.38%	0
1960	4.2%	-0.6%	0	4.41%	0
1961	3.9%	3.6%	0	4.35%	0
1962	2.2%	4.4%	0	4.33%	0
1963	1.0%	3.8%	0	4.26%	0
1964	6.0%	4.5%	0	4.40%	0
1965	0.5%	5.7%	0	4.49%	0
1966	1.1%	4.6%	0	5.13%	0
1967	1.9%	2.0%	0	5.51%	0
1968	4.2%	4.4%	0	6.18%	0
1969	2.1%	3.7%	0	7.03%	0
1970	3.8%	3.3%	0	8.04%	0
1971	4.2%	6.8%	0	7.39%	0
1972	8.0%	7.2%	0	7.21%	0
1973	0.6%	6.3%	0	7.44%	0
1974	5.9%	4.2%	0	8.57%	0
1975	14.2%	9.4%	0	8.83%	0
1976	10.7%	9.1%	0	8.43%	0
1977	6.1%	8.6%	0	8.02%	0
1978	7.6%	7.8%	0	8.73%	0
1979	7.2%	8.2%	0	9.63%	0
1980	14.6%	6.6%	0	11.94%	0
1981	11.6%	9.9%	0	14.17%	0
1982	12.1%	3.7%	0	13.79%	0
1983	12.8%	5.6%	0	12.04%	0
1984	1.8%	7.4%	1	12.71%	0
1985	0.1%	4.0%	1	11.37%	0
1986	1.3%	3.8%	1	9.02%	0
1987	1.7%	3.1%	1	9.38%	0
1988	-3.2%	4.4%	1	9.71%	0
1989	-3.7%	4.1%	1	9.26%	0
1990	11.9%	4.2%	1	9.32%	1
1991	1.3%	2.9%	1	8.77%	1
1992	4.4%	5.1%	1	8.14%	1

Permanent Shift Hypothesis (Bush-Uretsky)

Constant		-0.0027	
Std Err of Y Est		0.0347	
R Squared		0.4322	
No. of Observations		44	
Degrees of Freedom		40	
	US IPr	Divestiture	Moody
X Coefficient(s)	0.3402	-0.0579	0.6489
Std Err of Coef.	0.2338	0.0152	0.2093
t-Statisic	1.4553	-3.8142	3.1007
F-statistic	10.1512		
(3,40)			

Temporary Shift Hypothesis

Constant		-0.0061		
Std Err of Y Est		0.0309		
R Squared		0.5600		
No. of Observations		44		
Degrees of Freedom		39		
	US IPr	Divestiture	Moody	1990-1992
X Coefficient(s)	0.3209	-0.0851	0.7174	0.0740
Std Err of Coef.	0.2085	0.0158	0.1877	0.0220
t-Statisic	1.5392	-5.3981	3.8225	3.3658
F-statistic	12.4114			
(4,39)				

Source: CC: Docket 94-1, First Report and Order, Released April 7, 1995. Appendix F, Christensen Affidavit Data

REGRESSION: TELEPHONE INPUT PRICE GROWTH - CHRISTENSEN 2 DATA

Year	LEC Input Price Change	U.S. Input Price Change	Divestiture Binary Dummy	Yield on Moody's Pub Util Bonds	1990-2 Dummy
A	B	C	D	E	F
1960	2.4%	1.7%	0	4.41%	0
1961	4.0%	2.9%	0	4.35%	0
1962	3.1%	4.5%	0	4.33%	0
1963	4.9%	3.9%	0	4.26%	0
1964	2.4%	5.4%	0	4.40%	0
1965	2.4%	4.4%	0	4.49%	0
1966	1.5%	5.5%	0	5.13%	0
1967	5.0%	2.8%	0	5.51%	0
1968	6.1%	6.4%	0	6.18%	0
1969	2.7%	4.0%	0	7.03%	0
1970	4.0%	3.2%	0	8.04%	0
1971	6.5%	6.6%	0	7.39%	0
1972	7.6%	6.0%	0	7.21%	0
1973	6.6%	8.6%	0	7.44%	0
1974	4.8%	4.2%	0	8.57%	0
1975	9.3%	8.5%	0	8.83%	0
1976	9.2%	9.2%	0	8.43%	0
1977	4.8%	7.3%	0	8.02%	0
1978	7.3%	7.0%	0	8.73%	0
1979	2.9%	7.7%	0	9.63%	0
1980	6.9%	7.0%	0	11.94%	0
1981	11.0%	9.5%	0	14.17%	0
1982	9.3%	3.1%	0	13.79%	0
1983	13.7%	6.2%	0	12.04%	0
1984	1.8%	6.5%	1	12.71%	0
1985	0.1%	4.0%	1	11.37%	0
1986	1.3%	3.8%	1	9.02%	0
1987	1.7%	3.2%	1	9.38%	0
1988	-3.2%	4.6%	1	9.71%	0
1989	-3.7%	4.2%	1	9.26%	0
1990	11.9%	4.3%	1	9.32%	1
1991	1.3%	2.9%	1	8.77%	1
1992	4.4%	5.1%	1	8.14%	1

Permanent Shift Hypothesis (Bush-Uretsky)

Constant		-0.0046	
Std Err of Y Est		0.0308	
R Squared		0.4440	
No. of Observations		33	
Degrees of Freedom		29	
	US IPr	Divestiture	Moody
X Coefficient(s)	0.3140	-0.0480	0.5794
Std Err of Coef.	0.3179	0.0144	0.2350
t-Statistic	0.9878	-3.3365	2.4653
F-statistic (3,29)	7.7208		

Temporary Shift Hypothesis

Constant		-0.0111		
Std Err of Y Est		0.0247		
R Squared		0.6553		
No. of Observations		33		
Degrees of Freedom		28		
	US IPr	Divestiture	Moody	1990-1992
X Coefficient(s)	0.2774	-0.0752	0.6916	0.0731
Std Err of Coef.	0.2549	0.0133	0.1903	0.0177
t-Statistic	1.0881	-5.6677	3.6345	4.1423
F-statistic (4,28)	13.3067			

Source: CC: Docket 94-1, First Report and Order, Released April 7, 1995. Appendix F, NERA Data

REGRESSION: INPUT PRICE DIFFERENTIAL - CHRISTENSEN 1 DATA

Year	LEC-US Input Price Growth	Divest Binary Dummy	Moody's Pub Util Bonds	1990-2 Dummy
A	B	C	D	E
1949	4.2%	0	2.66%	0
1950	-1.2%	0	2.62%	0
1951	0.9%	0	2.86%	0
1952	7.4%	0	2.96%	0
1953	-1.3%	0	3.20%	0
1954	1.3%	0	2.90%	0
1955	-1.2%	0	3.06%	0
1956	1.0%	0	3.36%	0
1957	-4.8%	0	3.89%	0
1958	2.8%	0	3.79%	0
1959	-1.6%	0	4.38%	0
1960	4.8%	0	4.41%	0
1961	0.3%	0	4.35%	0
1962	-2.2%	0	4.33%	0
1963	-2.8%	0	4.26%	0
1964	1.5%	0	4.40%	0
1965	-5.2%	0	4.49%	0
1966	-3.5%	0	5.13%	0
1967	-0.1%	0	5.51%	0
1968	-0.2%	0	6.18%	0
1969	-1.6%	0	7.03%	0
1970	0.5%	0	8.04%	0
1971	-2.6%	0	7.39%	0
1972	0.8%	0	7.21%	0
1973	-5.7%	0	7.44%	0
1974	1.7%	0	8.57%	0
1975	4.8%	0	8.83%	0
1976	1.6%	0	8.43%	0
1977	-2.5%	0	8.02%	0
1978	-0.2%	0	8.73%	0
1979	-1.0%	0	9.63%	0
1980	8.0%	0	11.94%	0
1981	1.7%	0	14.17%	0
1982	8.4%	0	13.79%	0
1983	7.2%	0	12.04%	0
1984	-5.6%	1	12.71%	0
1985	-3.9%	1	11.37%	0
1986	-2.5%	1	9.02%	0
1987	-1.4%	1	9.38%	0
1988	-7.6%	1	9.71%	0
1989	-7.8%	1	9.26%	0
1990	7.7%	1	9.32%	1
1991	-1.6%	1	8.77%	1
1992	-0.7%	1	8.14%	1

Permanent Shift Hypothesis (Bush-Uretsky)

Constant		-0.0157
Std Err of Y Est		0.0375
R Squared		0.1702
No. of Observations		44
Degrees of Freedom		41
	Divestiture	Moody
X Coefficient(s)	-0.0440	0.3464
Std Err of Coef.	0.0155	0.1944
t-Statistic	-2.8330	1.7818
F-statistic	4.2036	
(2,41)		

Temporary Shift Hypothesis

Constant		-0.0194	
Std Err of Y Est		0.0344	
R Squared		0.3179	
No. of Observations		44	
Degrees of Freedom		40	
	Divestiture	Moody	1990-1992
X Coefficient(s)	-0.0701	0.4045	0.0721
Std Err of Coef.	0.0168	0.1796	0.0245
t-Statistic	-4.1737	2.2527	2.9429
F-statistic	6.2128		
(3,40)			

Source: CC: Docket 94-1, First Report and Order, Released April 7, 1995. Appendix F, Christensen Affidavit Data

REGRESSION: INPUT PRICE DIFFERENTIAL - CHRISTENSEN 2 DATA

Year	LEC-US Input Price Growth	Divestiture Binary Dummy	Yield on Moody's Pub Util Bonds	1990-2 Dummy
A	B	B	D	E
1960	0.7%	0	4.41%	0
1961	1.1%	0	4.35%	0
1962	-1.4%	0	4.33%	0
1963	1.0%	0	4.26%	0
1964	-3.0%	0	4.40%	0
1965	-2.0%	0	4.49%	0
1966	-4.0%	0	5.13%	0
1967	2.2%	0	5.51%	0
1968	-0.3%	0	6.18%	0
1969	-1.3%	0	7.03%	0
1970	0.8%	0	8.04%	0
1971	-0.1%	0	7.39%	0
1972	1.6%	0	7.21%	0
1973	-2.0%	0	7.44%	0
1974	0.6%	0	8.57%	0
1975	0.8%	0	8.83%	0
1976	0.0%	0	8.43%	0
1977	-2.5%	0	8.02%	0
1978	0.3%	0	8.73%	0
1979	-4.8%	0	9.63%	0
1980	-0.1%	0	11.94%	0
1981	1.5%	0	14.17%	0
1982	6.2%	0	13.79%	0
1983	7.5%	0	12.04%	0
1984	-4.7%	1	12.71%	0
1985	-3.9%	1	11.37%	0
1986	-2.5%	1	9.02%	0
1987	-1.5%	1	9.38%	0
1988	-7.8%	1	9.71%	0
1989	-7.9%	1	9.26%	0
1990	7.6%	1	9.32%	1
1991	-1.6%	1	8.77%	1
1992	-0.7%	1	8.14%	1

Permanent Shift Hypothesis (Bush-Uretsky)

Constant		-0.0251
Std Err of Y Est		0.0327
R Squared		0.1848
No. of Observations		33
Degrees of Freedom		30
	Divestiture	Moody
X Coefficient(s)	-0.0338	0.3419
Std Err of Coef.	0.0135	0.2200
t-Statistic	-2.4935	1.5543
F-statistic	3.4001	
(2,30)		

Temporary Shift Hypothesis

Constant		-0.0325	
Std Err of Y Est		0.0275	
R Squared		0.4395	
No. of Observations		33	
Degrees of Freedom		29	
	Divestiture	Moody	1990-1992
X Coefficient(s)	-0.0596	0.4390	0.0714
Std Err of Coef.	0.0135	0.1874	0.0197
t-Statistic	-4.4281	2.3422	3.6299
F-statistic	7.5787		
(3,29)			

Source: CC: Docket 94-1, First Report and Order, Released April 7, 1995. Appendix F, NERA Data

Attachment A

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